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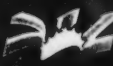
An All-Season Container and Bareroot Planting Trial of Lodgepole Pine and White Spruce: 14-Year Results

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An All-Season Container and Bareroot Planting Trial of Lodgepole Pine and White Spruce: 14-Year Results

by
P. LePage and J.C. Pollack

Research Section
B.C. Ministry of Forests and Lands
Smithers, B.C.

October 1986

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Canada



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ABSTRACT

An experiment was established in 1970 near McBride Lake, B.C., to assess the survival and growth of three stock types of white spruce (Picea glauca [Moench] Voss) and lodgepole pine (Pinus contorta Dougl. var latifolia Engelm.) at six different planting dates, and thereby to determine if it was possible to extend the planting season to the entire frost-free period.

The experiment was evaluated after the first, second, and fourth growing seasons. Following the fourth growing season large differences in survival and growth among species, stock types, and planting dates were noted. Spruce had better overall survival but lower average heights than pine for all stock types and planting dates. Bareroot stock had satisfactory survival (> 70%) for the October 1970 and May 1971 planting dates, but showed a steady decrease in survival as the 1971 planting season progressed. The survival of the plug stock was excellent throughout the entire frost-free period.

After the 14th growing season the experiment was re-evaluated. The differences in survival and growth among stock types and planting dates noted after 4 years remained virtually unchanged 10 years later. The decrease expected in such growth differences because of exposure to a common environment occurred slowly. Although differences among stock types and planting dates were less noticeable for lodgepole pine than for white spruce, significant differences were still present.

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1 INTRODUCTION

Recent national and provincial recognition of the vital role of reforestation to the forest economy has led to a dramatic increase in the number of trees planted annually. In 1983-84 the public and private sectors of the forest industry were responsible for planting over 112 million seedlings in British Columbia, a 51% increase over 1980. Unfortunately, the length of the planting season remains limited, often making the accomplishment of increased planting goals difficult.

To prolong the time available for planting, the traditional spring season is being extended to include the entire frost-free period. Historically, the survival and growth of late planted seedlings has been poor. Numerous studies, however (Tucker et al. 1968; Gardner 1981; McDonald et al. 1983; Krumlik 1984; Revel and Coates¹), indicate that under the correct conditions of storage, handling, stock type, and soil moisture and temperature, acceptable levels of survival and growth can be obtained. Experimental Project (EP) 697 was an early project designed to determine the rates of growth and survival of different stock types planted at various times throughout the growing season. Given the excellent condition of this long-deactivated experiment, and some basic similarities of the 1970 planting stock to modern stock types, a good opportunity was provided to evaluate a 14-year-old stock type x time of planting trial.

¹Revel, W.J. and H. Coates. 1982. Planting of white spruce throughout the growing season on high site areas in the sub-boreal forest region of British Columbia. B.C. Min. For., Prince George, B.C. Unpubl. report.

2 OBJECTIVES

The original objective of this trial was simply to relate the survival and growth rates of three stock types to the time of year in which they are planted, and thereby to determine if it is possible to extend the planting season with one or more treatments. Two tree species, white spruce (Picea glauca (Moench) Voss) and lodgepole pine (Pinus contorta Dougl. var. latifolia Engelm.), were tested. The re-examination of the experiment, 14 years after establishment, provided the opportunity to study the duration and magnitude of growth response differences attributed to stock type, storage time, and planting date.

3 LOCATION

Typical zonal ecosystems in the subalpine fir subzone, western variant of the Sub-Boreal Spruce Biogeoclimatic Zone (SBSel) were selected near McBride Lake in the Morice Forest District, Prince Rupert Forest Region (Figure 1). Blocks 1, 2, 5, and 6 are situated approximately 55 km southwest of Houston, B.C., at 54° 04'-06' north latitude by 127° 16'-21' west longitude. Blocks 3 and 4 are approximately 40 km southwest of Houston, just south of the Morice River at 54° 10' north latitude by 127° 07' west longitude. Complete stand, site, and soil descriptions for each block are listed in Table 1.

TABLE 1. Stand, site and soil descriptions for the all-season container and bare-root planting trial

Site	Species	Sub-zone	Assoc-iation ^a	Elevation (m)	Aspect (azimuth)	Slope (%)	Soil Description		Vegetative competition	Original stand ^b	Logged	Burned
							Texture	Sub-group				
1	Sw	S8Se1	/06	945	280°	7	Sandy clay	Brunisolic Grey Luvisol	Woody brush 10% willow & aspen	SP1B 831-M	1969-70	1970
2	P1	S8Se1	/06	945	290°	15	Sandy clay	Brunisolic Grey Luvisol	Woody brush 10% willow & aspen	SP1B 831-M	1969-70	1970
3	Sw	S8Se1	/06	792	330°	20	Loamy	Dystrophic Brunisol	Woody brush 10% willow & alder	SP1 831-M	1966	1970
4	Sw	S8Se1	/04(b)	853	80°	25	Sandy	Dystrophic Brunisol	Woody brush 5% alder & willow	SP1 831-M	1966	1970
5	P1	---	---	---	---	---	---	---	---	---	---	---
6	P1	S8Se1	/01	823	Flat	0	Sandy Loam	Eluviated Dystrophic Brunisol	Woody brush 5% alder & willow	SP1 831-M	1962	1970

^aBased on Pojar et al. 1984.^bBased on approximation from 1972 cruise of surrounding stands.

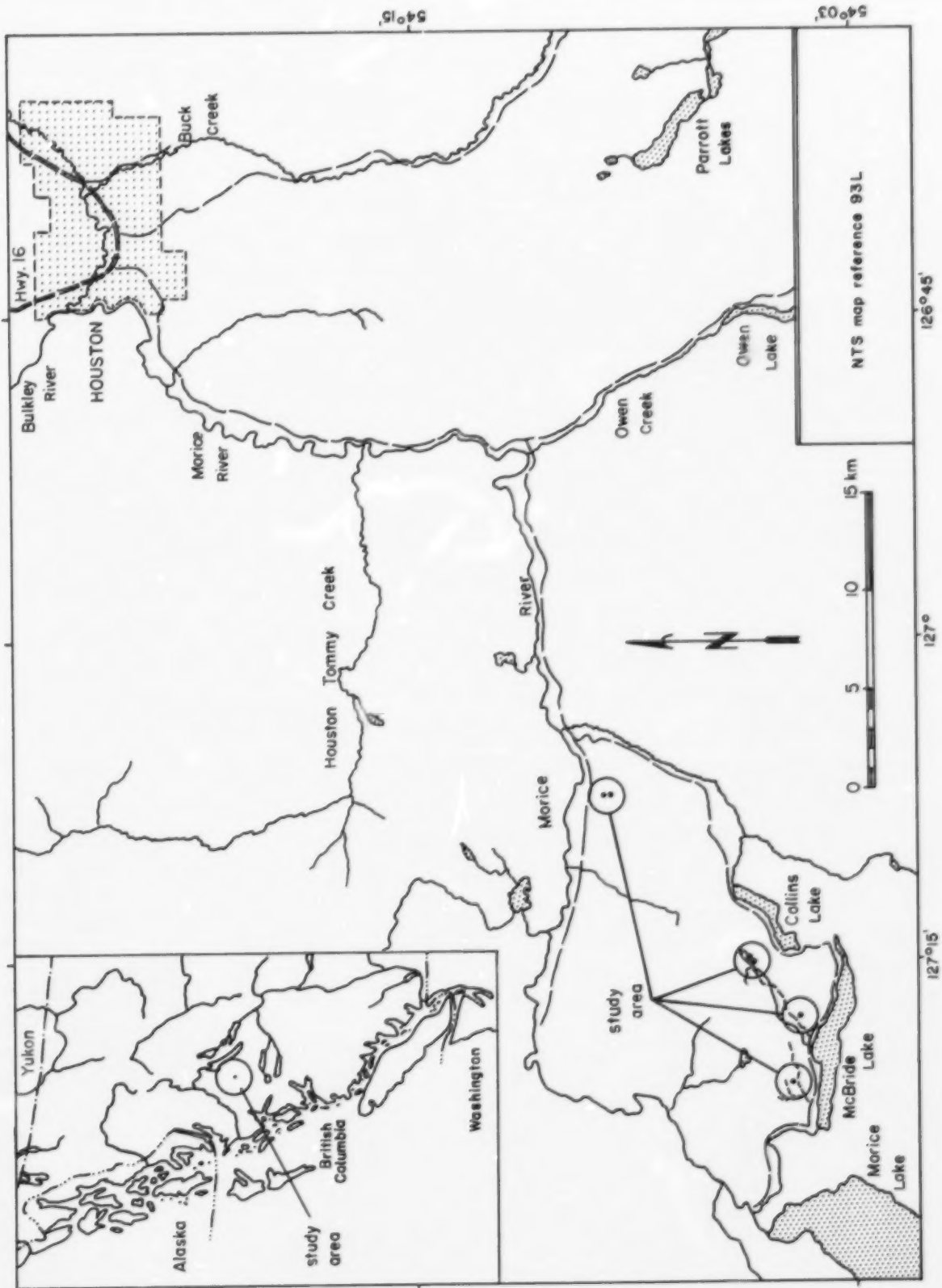


FIGURE 1. General location map of the study area.

4 METHODS

4.1 Trial Design and Layout

The experiment used a completely randomized design in which each of the two species was tested on three different sites. The factors examined at each site were as follows:

<u>Factor</u>	<u>Levels</u>
Stock types	3 - PSB-211 1+0, Prototype bullet 1+0 and Bareroot 2+0
Planting dates	6 - Oct. 1970, May 1971, June 1971, July 1971, Aug. 1971, Sept. 1971

Each site or block contained only one species -- white spruce or lodgepole pine -- for a total of six sites. Each site consisted of 36 line plots representing two replications of the three stock types and six planting dates. Treatments were assigned to each line on a completely randomized basis. A summary of the experimental layout is given in Table 2. Individual line plots contained 50 seedlings with between-tree spacings of 1 m and between-line spacings of 2 m.

4.2 The Planting Stock

The experiment involved two species: white spruce, seedlot #937, and lodgepole pine, seedlot #1427; and three stock types: PSB-211 1+0, prototype bullet 1+0, and bareroot 2+0. The PSB-211 1+0 and the 1+0 bullet stock were sown in the spring of 1970 at the Canadian Forestry Service Burnside nursery and transported to the Telkwa nursery in the early summer of the same year. These stocks were retained in their containers, watered and fertilized as required, and were not cold stored.

The 2+0 bareroot stock was sown in the spring of 1969 at the B.C. Ministry of Forests Red Rock nursery. Bareroot stock selected for the October 1970 planting was lifted in the late fall, and immediately planted without cold storage. The remainder of the stock was lifted in April 1971 and cold stored until required for the 1971 plantings, a duration of 1-5 months.

TABLE 2. Experimental layout by block, species, replicate number, stock type, and planting date

Line no.	Block number and species				
	1 White spruce	2 Lodgepole pine	3 White spruce	4 White spruce	6 Lodgepole pine
1	1B1 ^a	2B2	1B5	1B6	1B2
2	1C1	1P1	1C5	2C5	2C1
3	2P2	2P6	1P4	1P2	1C6
4	1B2	1B2	1B1	1B2	1B1
5	2C3	1C1	1B4	1B1	1P6
6	2P1	2C5	2B5	1P4	1C4
7	1P1	1B6	1C3	1P3	2P4
8	1P6	1P2	2P2	2P4	1C1
9	2B1	2B5	1P2	2C2	1C2
10	2B5	2C4	2P1	2C3	2P5
11	1C5	2B4	1C2	1P4	2B5
12	2B4	2C2	2C2	2C6	2P1
13	1P2	1P6	2C4	2B2	1P5
14	2P6	1C5	1C4	1B3	2B3
15	2C5	2P3	2C6	2P5	2B4
16	2P4	1B3	1P6	2P6	1C5
17	1C2	1P5	2C3	1C1	2B1
18	2C4	1C4	2C5	1B5	1B3
19	2B3	2C3	1P1	2B1	2P3
20	1B3	2B1	2P6	2P1	2C4
21	1C6	2P1	2B1	2B6	2C5
22	1B6	1C6	2B6	1C6	1P2
23	2C6	2P4	2C1	2C4	2C6
24	1P3	2P5	2B2	1P6	1C3
25	1B4	2B3	1B6	2B5	1P1
26	1P4	2P2	1P3	2B4	2B6
27	1C4	2C1	1C1	1C5	2P2
28	2C1	1P4	2B3	2B3	1B5
29	2G2	1P3	2P5	2P2	2C2
30	2P5	1B1	1B3	1C2	2C3
31	1P5	1B4	2P4	1C3	2B6
32	2B6	2B6	1C6	2C1	1B4
33	2B2	1C3	1B2	1P1	2B2
34	2P3	2C5	2B4	1C4	1P3
35	1B5	1B5	2P3	2P3	1P4
36	1C3	1C2	1P5	1P5	2P6

^a1st position=replicate number (1 or 2)

2nd position=stock type: P=PSB-211 1+0

B=Bareroot 2+0

C=Prototype bullet 1+0

3rd position=planting date; 1=Oct. 1970 4=July 1971

2=May 1971 5=Aug. 1971

3=June 1971 6=Sept. 1971

4.3 Work History to Date

The first complete examination of the trial, which took place in the late fall of 1971, assessed overall survival, tree condition, and pathology. Subsequent examinations in the spring and fall of 1972 and the fall of 1974 recorded survival and tree condition for all trees and total height and leader increment for 10 randomly selected trees in each of the thirty-six 50-tree line plots per block.

The latest examination of the experiment was in the fall of 1984, 14 years after establishment. At this time all 50 trees in each plot were assessed for survival, and 25 trees in each plot were measured for total height (nearest centimetre) and DBH outside bark (nearest 0.1 cm). During the 1984 assessment it was found that the sequence of treatments for block 5 did not agree with either the establishment report or with any of the previous assessments as recorded in the field notes. For this reason block 5 was deleted from the analysis.

4.4 Analyses

The 1974 fourth-year report by Chapman presented treatment means and a number of graphs for height and survival versus planting date.² For this assessment, these data were re-examined, block 5 (lodgepole pine) was deleted, and treatment means and standard errors were recalculated as shown in Tables 3 and 4.

The 14-year data were of primary interest to this study. Univariate statistics for percent survival and mean height were determined for the various stock types and planting dates (Tables 5 and 6). These values were plotted for the two species, shown Figures 2-5. Analyses of variance (ANOVA) were performed on survival and height data for both species (Table 7). To compare the overall performance of the three stock types, planting dates were pooled for each species (Table 8). Finally, comparisons were made of the 4 and 14-year rankings of mean height by planting date in which the stock types were pooled (Table 9), and for individual stock types and planting dates (Tables 10-12).

²Chapman, B. 1974. EP 697 - Container grown and bareroot trials in the interior. B.C. Min. For. Unpubl. report.

Table 3. Mean survival of white spruce and lodgepole pine stock types 4 years after planting (excluding block 5 data)

Species	Stock type ^a	Time of planting					Mean survival (%) $\pm$ SE ^b
		Oct. 1970	May 1971	June 1971	July 1971	Aug. 1971	Sept. 1971
Sw	B	89.9 $\pm$ 1.2	86.0 $\pm$ 6.1	60.3 $\pm$ 5.9	41.3 $\pm$ 8.8	37.7 $\pm$ 10.3	31.7 $\pm$ 3.1
Sw	C	73.9 $\pm$ 9.7	62.3 $\pm$ 6.8	73.8 $\pm$ 7.2	33.7 $\pm$ 5.4	70.0 $\pm$ 8.2	69.0 $\pm$ 5.9
Sw	P	78.6 $\pm$ 4.7	89.0 $\pm$ 4.9	83.7 $\pm$ 5.3	74.0 $\pm$ 7.3	86.0 $\pm$ 5.5	86.3 $\pm$ 6.5
Pl	B	74.4 $\pm$ 3.7	63.0 $\pm$ 13.5	64.6 $\pm$ 8.8	41.4 $\pm$ 10.3	10.7 $\pm$ 2.6	18.7 $\pm$ 6.8
Pl	C	75.0 $\pm$ 7.0	68.5 $\pm$ 15.4	68.0 $\pm$ 6.3	14.5 $\pm$ 7.9	74.4 $\pm$ 1.1	69.0 $\pm$ 5.1
Pl	P	78.4 $\pm$ 8.6	90.5 $\pm$ 3.9	89.0 $\pm$ 5.3	81.0 $\pm$ 3.3	90.5 $\pm$ 4.3	89.5 $\pm$ 2.4

^aB = Bareroot 2+0

C = Prototype bullet 1+0

P = PSB-211 1+0

^bBased on n = 6 for white spruce and n = 4 for lodgepole pine.

TABLE 4. Mean total height of white spruce and lodgepole pine stock types 4 years after planting (excluding block 5 data)

Species	Stock type ^a	Time of planting					
		Oct. 1970	May 1971	June 1971	July 1971	Aug. 1971	Sept. 1971
		Mean total height (cm) $\pm$ SE ^b					
Sw	B	45.9+2.3 (60)	44.0+2.5 (60)	30.8+1.7 (60)	21.5+1.2 (60)	16.3+1.1 (60)	14.2+0.7 (60)
Sw	C	27.4+1.5 (60)	24.4+1.5 (60)	25.3+1.6 (60)	17.7+1.4 (55)	17.0+1.2 (60)	16.4+0.7 (60)
Sw	P	41.0+2.0 (60)	41.6+2.5 (60)	32.5+1.7 (60)	33.2+1.8 (60)	24.5+1.1 (60)	22.9+1.3 (60)
Pl	B	78.3+4.1 (40)	58.7+3.7 (40)	53.1+3.2 (40)	45.1+3.4 (40)	25.0+2.8 (21)	30.2+2.8 (30)
Pl	C	48.8+3.0 (40)	54.9+3.0 (40)	52.5+2.8 (40)	34.1+4.0 (20)	32.0+1.9 (40)	31.7+1.7 (40)
Pl	P	68.0+3.8 (40)	73.7+3.6 (40)	78.1+3.3 (40)	58.3+3.3 (40)	41.5+2.0 (40)	42.8+2.0 (40)

^aB = Bareroot 2+0

C = Prototype bullet 1+0

P = PSB-211 1+0

^bIndividual n values in brackets.

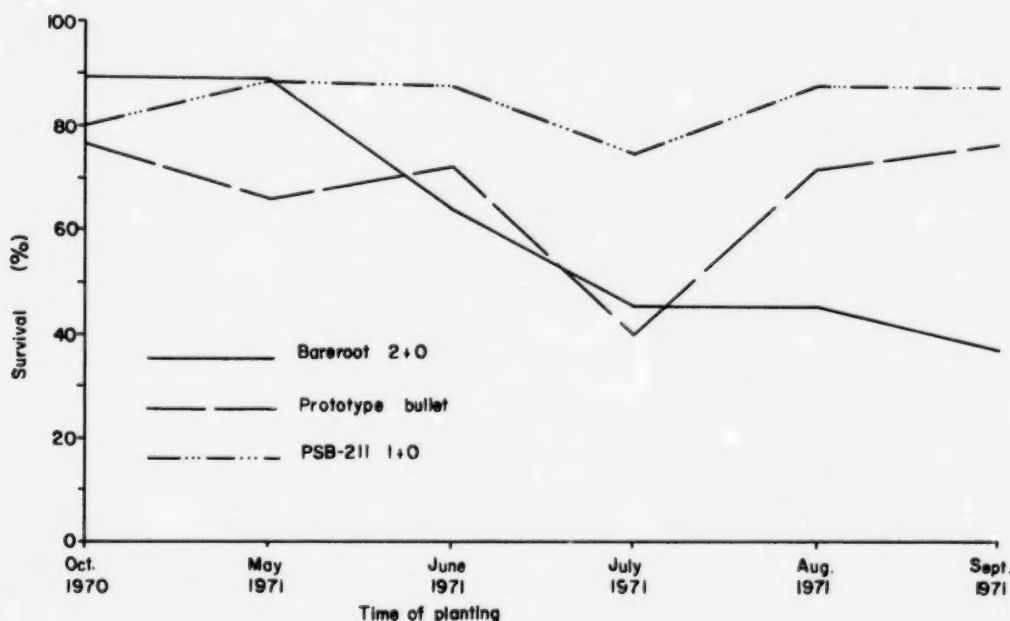


FIGURE 2. Graph of survival vs planting date for the three stock types of white spruce.

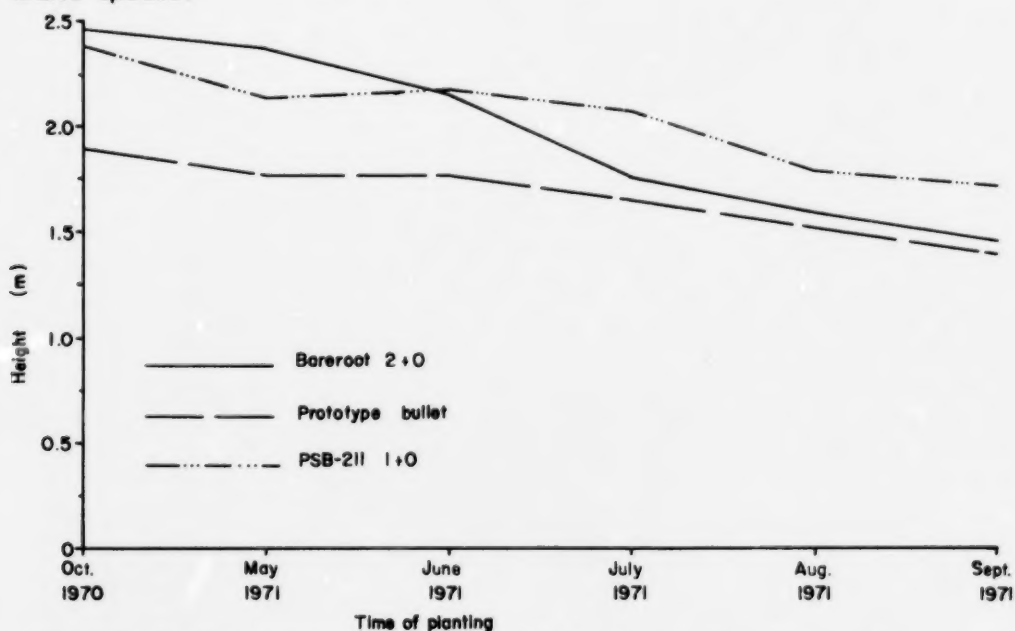


FIGURE 3. Graph of height vs planting date for the three stock types of white spruce.

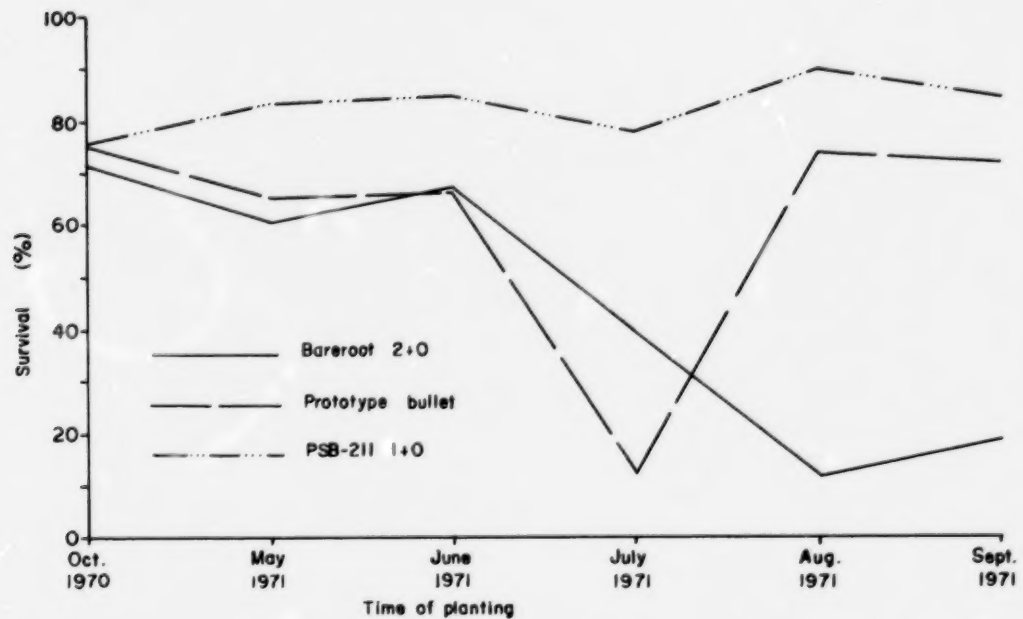


FIGURE 4. Graph of survival vs planting date for the three stock types of lodgepole pine.

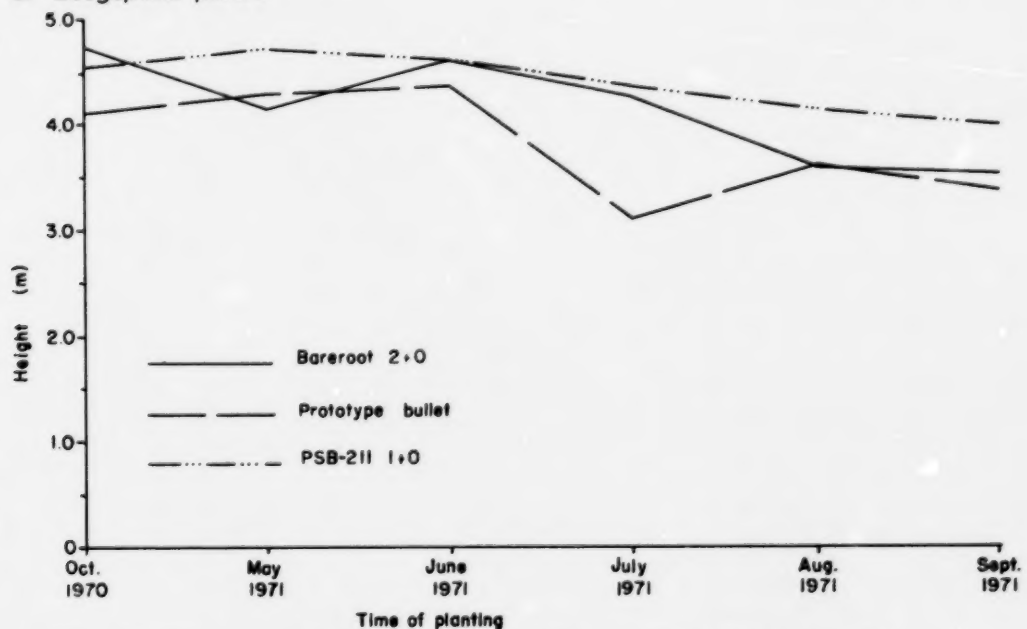


FIGURE 5. Graph of height vs planting date for the three stock types of lodgepole pine.

TABLE 5. Survival of white spruce and lodgepole pine stock types 14 years after planting

Species	Stock type ^a	Time of planting					Aug. 191	Sept. 1971
		Oct. 1970	May 1971	June 1971	July 1971	Survival (%) ± SE ^b		
Sw	B	89.2±0.2	88.8±1.3	64.1±1.1	45.5±1.4	45.5±2.4	37.5±0.9	
Sw	C	76.5±1.5	65.8±2.1	72.2±1.8	39.8±1.7	71.5±2.1	77.0±1.4	
Sw	P	80.0±0.8	89.0±1.1	87.9±0.8	74.4±1.7	87.8±1.2	87.1±1.4	
Pl	B	71.9±0.8	60.2±1.8	67.3±1.5	39.0±1.6	11.7±0.5	18.7±1.0	
Pl	C	75.6±0.9	65.6±2.6	66.8±1.1	12.2±1.2	73.5±0.6	72.0±1.0	
Pl	P	75.8±1.5	83.1±1.1	84.6±1.1	77.8±0.4	89.8±0.7	84.2±0.7	

^aB = Bareroot 2+0

C = Prototype bullet 1+0

P = PSB-211 1+0

^bBased on n = 6 for white spruce and n = 4 for lodgepole pine.

TABLE 6. Mean total height of white spruce and lodgepole pine stock types 14 years after planting

Species	Stock type ^a	<u>Time of planting</u>					
		Oct. 1970	May 1971	June 1971	July 1971	Aug. 1971	Sept. 1971
		Mean total height (m) + SE ^b					
Sw	B	2.46+0.07 (108)	2.37+0.07 (106)	2.15+0.07 (112)	1.74+0.08 (88)	1.58+0.07 (75)	1.45+0.06 (83)
Sw	C	1.90+0.06 (122)	1.77+0.06 (98)	1.77+0.06 (106)	1.64+0.07 (81)	1.50+0.05 (117)	1.38+0.05 (118)
Sw	P	2.39+0.08 (111)	2.13+0.08 (102)	2.17+0.07 (105)	2.07+0.07 (98)	1.78+0.07 (102)	1.71+0.06 (121)
Pl	B	4.73+0.09 (86)	4.16+0.14 (84)	4.59+0.08 (85)	4.27+0.11 (62)	3.61+0.18 (26)	3.55+0.15 (37)
Pl	C	4.10+0.09 (87)	4.28+0.09 (79)	4.37+0.07 (88)	3.11+0.33 (23)	3.62+0.10 (91)	3.39+0.10 (87)
Pl	P	4.55+0.08 (83)	4.70+0.08 (83)	4.60+0.08 (76)	4.35+0.11 (85)	4.14+0.08 (89)	4.01+0.09 (93)

^aB = Bareroot 2+0

C = Prototype bullet 1+0

P = PSB-211 1+0

^bIndividual n values in brackets.

TABLE 7. Analyses of variance for white spruce and lodgepole pine 14 years after planting

Source of variation	df	White spruce ^a		Mean squares		Lodgepole pine ^{a, b}	
		Survival	Height	df		Survival	Height
Block	2	6612**	14.1**	1		1235**	2.6
Stock	2	4666**	79.9**	2		8734**	30.8**
Date	5	1867**	25.1**	5		1727**	27.3**
Stock x date	10	1077**	1.5	10		1624**	4.1
Block interactions	34	239	0.9	17		269	3.4

^a *significant at 0.05 level

**significant at 0.01 level

^bExcluding block 5 data.

TABLE 8. Characteristics of white spruce and lodgepole pine stock types 14 years after planting (planting dates pooled)

Species	Stock type	Percent survival (%) $\pm$ SE	Mean total height (m) $\pm$ SE
White spruce	Bareroot 2+0	61.2 $\pm$ 1.0 (36) ^a	2.01 $\pm$ 0.03 (572)
"	Prototype bullet 1+0	67.2 $\pm$ 0.9 (36)	1.66 $\pm$ 0.03 (642)
"	PSB-211 1+0	84.4 $\pm$ 0.5 (36)	2.04 $\pm$ 0.03 (639)
Lodgepole pine	Bareroot 2+0	43.4 $\pm$ 1.1 (24)	4.31 $\pm$ 0.05 (380)
"	Prototype bullet 1+0	60.2 $\pm$ 1.1 (24)	3.90 $\pm$ 0.05 (455)
"	PSB-211 1+0	82.6 $\pm$ 0.4 (24)	4.38 $\pm$ 0.04 (509)

^aIndividual n values in brackets.

TABLE 9. Absolute and relative mean height differences among planting dates, 4 and 14 years after planting (stock types pooled)

Species	Planting date ^a	1974 n	1974 Mean height (m) $\pm$ SE	Relative percent (%)	1984 n ^b	1984 Mean height (m) $\pm$ SE	Relative percent (%)
Sw	1	180	0.381 $\pm$ 0.013	100.0	341	2.24 $\pm$ 0.04	100.0
Sw	2	180	0.366 $\pm$ 0.014	96.1	306	2.10 $\pm$ 0.04	93.8
Sw	3	180	0.295 $\pm$ 0.010	77.4	323	2.03 $\pm$ 0.04	90.6
Sw	4	174	0.243 $\pm$ 0.010	63.8	267	1.83 $\pm$ 0.04	81.7
Sw	5	176	0.193 $\pm$ 0.007	50.7	294	1.62 $\pm$ 0.04	72.3
Sw	6	180	0.178 $\pm$ 0.006	46.7	322	1.53 $\pm$ 0.03	68.3
P1	1	120	0.650 $\pm$ 0.024	100.0	256	4.46 $\pm$ 0.05	100.0
P1	2	120	0.624 $\pm$ 0.021	96.0	246	4.38 $\pm$ 0.06	98.2
P1	3	120	0.612 $\pm$ 0.021	94.2	249	4.51 $\pm$ 0.04	101.1
P1	4	100	0.482 $\pm$ 0.022	74.2	170	4.15 $\pm$ 0.09	93.0
P1	5	101	0.343 $\pm$ 0.014	52.8	206	3.84 $\pm$ 0.06	86.1
P1	6	110	0.354 $\pm$ 0.013	54.5	217	3.68 $\pm$ 0.06	82.5

^a1 = Oct. 1970, 2 = May 1971, 3 = June 1971

4 = July 1971, 5 = Aug. 1971, 6 = Sept. 1971

^b1984 n values exceed 1974 values because of a greater sampling intensity.

TABLE 10. Absolute and relative mean height differences among planting dates of PSB-211 stock, 4 and 14 years after planting

Species	Planting date ^a	1974 n	1974 Mean height (m) $\pm$ SE	Relative percent (%)	1984 n ^b	1984 Mean height (m) $\pm$ SE	Relative percent (%)
Sw	1	60	0.410 $\pm$ 0.020	100.0	111	2.39 $\pm$ 0.075	100.0
Sw	2	60	0.416 $\pm$ 0.025	101.5	102	2.13 $\pm$ 0.082	89.1
Sw	3	60	0.325 $\pm$ 0.017	79.3	105	2.17 $\pm$ 0.073	90.8
Sw	4	60	0.332 $\pm$ 0.018	81.0	98	2.07 $\pm$ 0.072	86.6
Sw	5	60	0.244 $\pm$ 0.011	59.5	102	1.78 $\pm$ 0.069	74.5
Sw	6	60	0.229 $\pm$ 0.013	55.8	121	1.71 $\pm$ 0.063	71.6
P1	1	40	0.680 $\pm$ 0.038	100.0	83	4.55 $\pm$ 0.077	100.0
P1	2	40	0.737 $\pm$ 0.036	108.4	83	4.70 $\pm$ 0.075	103.3
P1	3	40	0.781 $\pm$ 0.033	114.9	76	4.60 $\pm$ 0.076	101.1
P1	4	40	0.583 $\pm$ 0.033	85.7	85	4.35 $\pm$ 0.109	95.6
P1	5	40	0.416 $\pm$ 0.020	61.2	89	4.14 $\pm$ 0.083	91.0
P1	6	40	0.428 $\pm$ 0.020	62.9	93	4.01 $\pm$ 0.089	88.1

^a1 = Oct. 1970, 2 = May 1971, 3 = June 1971

4 = July 1971, 5 = Aug. 1971, 6 = Sept. 1971

^b1984 n values exceed 1974 values because of a greater sampling intensity.

TABLE 11. Absolute and relative mean height differences among planting dates of bareroot 2+0 stock, 4 and 14 years after planting

Species	Planting date ^a	1974 n	1974 Mean height (m) $\pm$ SE	Relative percent (%)	1984 n ^b	1984 Mean height (m) $\pm$ SE	Relative percent (%)
Sw	1	60	0.459 $\pm$ 0.023	100.0	108	2.46 $\pm$ 0.074	100.0
Sw	2	60	0.440 $\pm$ 0.025	95.9	106	2.37 $\pm$ 0.073	96.3
Sw	3	60	0.308 $\pm$ 0.017	67.1	112	2.15 $\pm$ 0.073	87.4
Sw	4	59	0.215 $\pm$ 0.012	46.8	88	1.75 $\pm$ 0.076	71.1
Sw	5	56	0.163 $\pm$ 0.011	35.5	75	1.58 $\pm$ 0.068	64.2
Sw	6	60	0.142 $\pm$ 0.007	30.9	83	1.45 $\pm$ 0.057	58.9
P1	1	40	0.783 $\pm$ 0.041	100.0	86	4.73 $\pm$ 0.092	100.0
P1	2	40	0.587 $\pm$ 0.037	75.0	84	4.16 $\pm$ 0.136	87.9
P1	3	40	0.531 $\pm$ 0.032	67.8	85	4.59 $\pm$ 0.077	97.0
P1	4	40	0.451 $\pm$ 0.034	57.6	62	4.27 $\pm$ 0.111	90.3
P1	5	21	0.250 $\pm$ 0.028	31.9	26	3.61 $\pm$ 0.182	76.3
P1	6	30	0.302 $\pm$ 0.028	38.6	37	3.55 $\pm$ 0.154	75.1

^a1 = Oct. 1970, 2 = May 1971, 3 = June 1971

4 = July 1971, 5 = Aug. 1971, 6 = Sept. 1971

^b1984 n values exceed 1974 values because of a greater sampling intensity.

TABLE 12. Absolute and relative mean height differences among planting dates of prototype bullet stock, 4 and 14 years after planting

Species	Planting date ^a	1974 n	1974 Mean height (m) $\pm$ SE	Relative percent (%)	1984 n ^b	1984 Mean height (m) $\pm$ SE	Relative percent (%)
Sw	1	60	0.274 $\pm$ 0.015	100.0	122	1.90 $\pm$ 0.064	100.0
Sw	2	60	0.244 $\pm$ 0.015	89.1	98	1.77 $\pm$ 0.058	93.2
Sw	3	60	0.253 $\pm$ 0.016	92.3	106	1.77 $\pm$ 0.063	93.2
Sw	4	60	0.177 $\pm$ 0.014	64.6	81	1.64 $\pm$ 0.073	86.3
Sw	5	60	0.170 $\pm$ 0.012	62.0	117	1.50 $\pm$ 0.055	78.9
Sw	6	60	0.164 $\pm$ 0.007	59.9	118	1.38 $\pm$ 0.054	72.6
P1	1	40	0.488 $\pm$ 0.030	100.0	87	4.10 $\pm$ 0.090	100.0
P1	2	40	0.548 $\pm$ 0.029	112.3	79	4.29 $\pm$ 0.090	104.6
P1	3	40	0.525 $\pm$ 0.028	107.6	88	4.37 $\pm$ 0.072	106.6
P1	4	20	0.341 $\pm$ 0.040	69.9	23	3.11 $\pm$ 0.333	75.9
P1	5	40	0.320 $\pm$ 0.019	65.6	91	3.62 $\pm$ 0.095	88.3
P1	6	40	0.317 $\pm$ 0.017	65.0	87	3.39 $\pm$ 0.098	82.7

^a1 = Oct. 1970, 2 = May 1971, 3 = June 1971

4 = July 1971, 5 = Aug. 1971, 6 = Sept. 1971

^b1984 n values exceed 1974 values because of a greater sampling intensity.

5 RESULTS

5.1 1974 Analysis

Four years after planting, survival rates for both spruce and pine exhibit the same trends for each of the six planting date treatments. The spruce stock had slightly better overall survival but lower average heights than the pine for most stock types and planting dates (Tables 3 and 4). The bareroot stock showed satisfactory survival ($>70\%$) for the October 1970 and May 1971 planting dates only. Bullet stock exhibited poor survival when planted during the mid-summer (July) and was only marginally acceptable for spring and fall planting. The lowest survival rates were associated with the July plantations. By far the best overall survival was obtained with the PSB-211 stock. Survival in excess of 70% was attained by both species for all planting dates.

5.2 1984 Analysis

The 14-year results show trends surprisingly similar to those of the 4-year analysis. The white spruce had generally higher overall survival but lower average heights than the lodgepole pine for all stock types and planting dates (Tables 5 and 6). The bareroot stock showed acceptable survival ($>70\%$) for the October 1970 and May 1971 planting dates only with a steady decline through the planting season.

The performance of the prototype bullet stock remained unsuccessful during the summer months and only marginally acceptable for the spring and fall planting dates. After 14 years, the data indicate that the best survival and height growth were still attributed to the PSB-211 stock for all planting dates. The only exceptions to this trend were during the October and May planting dates when the white spruce bareroot stock had greater mean heights.

Figures 2-5 show that while height growth is similar throughout the growing season for all stock types, only the PSB-211 stock exhibits associated satisfactory survival for all the planting dates.

The ANOVA's for height of white spruce and lodgepole pine (Table 7) indicate that significant differences still exist among stock types and planting dates 14 years after planting. Table 9 lists the relative mean height differences among planting dates for stock types pooled. The data indicate that, after 14 years, while the absolute differences in total height among planting dates are increasing, the relative differences are decreasing. Tables 10-12 present similar information for each stock type; the same trend of increasing absolute and decreasing relative height differences was observed in each case.

6 DISCUSSION

6.1 Stock Types

In this experiment, significant differences among stock types were measured in the total heights and survival of both species, 14 years after planting (Table 7). When planting dates are pooled, PSB-211 stock exhibited the best survival of any stock type: 82.6% for lodgepole pine and 84.4% for white spruce (Table 8). The other two stock types demonstrated considerably poorer survival, ranging from 67.2 to 43.4%, depending upon species and stock type.

The lower survival rates of the 2+0 bareroot and prototype bullet stocks are attributable to two factors. In the case of the bareroot stock, prolonged cold storage reduced both survival and, to some degree, the height growth of surviving saplings (Tables 5 and 6). An additional factor in the case of the prototype bullet stock is the impenetrable plastic shell which enclosed much of the rooting volume of the seedling. Unable to gain sufficient root contact with the surrounding soil, bullet seedlings suffered severe moisture deficits resulting in poor survival and greatly reduced height growth. The effects of this initial root restriction have persisted for 14 years and they are apparent among stock types for all planting dates. In 1984, the average white spruce bullet sapling was 1.66 m tall as compared with 2.01-m bareroot and 2.04-m PSB-211 saplings (Table 8). Although less pronounced, similar effects were observed in the height of lodgepole pine. The average heights of PSB-211 stock and 2+0 bareroot stock within species were nearly identical after 14 years.

6.2 Planting Dates

Among planting dates, significant differences were observed in the total heights and survival of both species, 14 years after planting (Table 7). PSB-211 stock for both white spruce and lodgepole pine showed excellent survival when hot-planted throughout the season; the lowest

survival rate for either species was 74.4% for white spruce planted in July 1971 (Table 5). Prototype bullet stock fared much worse; in general, this stock type had 10-15% lower survival for a given planting date than the PSB-211 stock. Mid-season planting of bullet stock in July 1971 was unsuccessful, with survival rates of 39.8% and 12.2% for white spruce and lodgepole pine, respectively. Again, it appears the impenetrable plastic shell of this stock type resulted in severe moisture deficits, particularly when planted in hot weather.

For bareroot stock, the effect of planting date was most pronounced and inseparably confounded with storage length. Acceptable survival occurred only in the fall of 1970 and spring of 1971 for both species. The continued decline in survival of the 2+0 stock with each successive planting date indicates the detrimental effects of prolonged cold storage. This trend has been noted in other studies (Clark 1967; Cram and Lindquist 1981; McDonald et al. 1983; Revel and Coates³).

The most interesting effect observed in this experiment is the continued influence of planting date on the mean height of all stock types 14 years later. When stock types were pooled (Table 9), white spruce seedlings planted on the last planting date were 68.3% of the height of seedlings planted at the earliest date. Lodgepole pine seedlings were 82.5% for the same comparison.

Examination of the individual stock types showed similar declines in total height with delayed planting (Tables 10-12). After four seasons, PSB-211 white spruce stock planted in the fall of 1971 was 55.8% the height of stock planted in the fall of 1970. After 14 years this relative height difference had decreased, with the fall, 1971, stock increasing to 71.6% the height of the fall, 1970, stock. This reduced total height as a result of delayed planting was more adverse with bareroot stock than with either the prototype bullet or PSB-211 stock, and lodgepole pine was less affected than white spruce.

³Revel and Coates, 1982.

It is interesting to note that while the relative difference in height among the six planting dates has decreased with time, the absolute difference has increased. The mean 4-year absolute height difference among planting dates for PSB-211 stock was 18.7 cm for white spruce and 36.5 cm for lodgepole pine. These differences increased to 68.0 cm and 69.0 cm, respectively, after the 14th growing season (Table 10).

Examination of individual stock types revealed that the larger 2+0 bareroot stock reduced its relative height differences among planting dates more rapidly than did the other stock types. Evidently, although the survival of the bareroot stock was the poorest, those late-planted seedlings that did survive grew faster than the other stock types. The PSB-211 stock maintained the highest survival levels, however, and its relative growth rate was only slightly less than the bareroot stock. The prototype bullet stock, through showing a better overall survival than the bareroot, grew very slowly.

6.3 Implications

When stock type and planting date effects are significant long after plantation establishment, silvicultural practices should be examined to determine where these effects could be important. This examination is complicated by the many advances in nursery culture that have been made since 1970. Stock types have changed, and the ones used in this study are somewhat different from those grown today. For example, modern 2+0 bareroot stock is probably better than that used 14 years ago. Unlike the bareroot stock used in this study, present-day dormant bareroot stock is not stored any longer than necessary to avoid cold-storage deterioration. Modern nursery men do not like to accept turnback of cold-stored, dormant bareroot stock for transplanting after July 1 for this reason.

Another major shift over the past 3 years has been the replacement of interior spruce 2+0 bareroot stock with the PSB-313A container. With lodgepole pine, however, the PSB-211 container yields excellent field performance and it remains the containerized stock of choice. Bullet stock of any type is not used operationally because of the moisture deficit and root egress problems mentioned earlier.

Late season planting also requires somewhat different cultural practices. Currently, non-dormant stock is hot-lifted after flush has been completed, the succulent tissues have lignified, and budset has been initiated. Although the hot-lifting techniques for late planting used in this study are similar to present practices, the culturing techniques and container size differ such that modern PSB-313A 2+0 seedlings would now have larger root collar diameters and root masses.

Despite these changes in nursery practice over the past 14 years, this study suggests three cases that warrant further investigation. First, there is the matter of brush-prone sites. A planting stock combining the higher survival of plug stock and the faster growth of larger stock (e.g., PSB-615 1+0 or PSB-313A 2+0) would have a better chance of outgrowing brush competition than other stock types. This conclusion is supported by LePage and Pollack⁴ who found significantly greater survival and growth responses on brush sites with PSB-615 1+0 Sitka spruce stock as compared with smaller stock sizes.

A second consideration is the current PSB-313A 2+0 white spruce nursery program. The evidence of this trial strongly supports the use of PSB-stock which, after 14 years, equalled the height growth of bareroot 2+0 stock. The PSB-211 1+0 stock in this trial was held in its containers and watered and fertilized as required, until it resembled PSB-211 2+0 stock when planted in late summer and early fall, 1971. Under these conditions, height growth was reduced. The obvious question is whether similar reductions in height growth could occur with the present PSB-313A 2+0 white spruce stock. Even if small reductions in height growth do occur with the PSB-313A stock, however, the benefits of less expensive seedlings, added nursery capacity,⁵ and improved survival may outweigh a chance of reduced height growth on brush sites. Approximately

⁴LePage, P. and J. Pollack. 1986. Development of vegetation management techniques for coastal alluvial sites - trials with large planting stock. EP 885.04. B.C. Min. For., Res. Branch, Smithers, B.C. Unpubl. progress report.

⁵Equivalent PSB-1+0 stock require substantially greater greenhouse facilities.

8 million 1-1/2+1/2 bareroot interior spruce seedlings are produced annually for sites with heavy brush competition, and further comparisons between this stock and large containers would be worthwhile (D. Armit, pers. comm., June 1986).

The third case worth considering is the duration of the stock type and planting date effects: how long do they persist? Studies by van den Driessche (1984), Krumlik and Bergerud (1985), and Revel⁶ all conclude that different stock types develop similar physical and morphological characteristics after planting as they adjust to a common environment. Krumlik and Bergerud (1985) and Mullin (1974) found that differences in survival and height among stock types have persisted up to 20 years after planting.

If this last case is indeed typical, then these effects may influence some types of nursery and reforestation decisions 2 or more decades after plantation establishment. Growth and yield foresters may find these effects will interfere with early site index determinations on highly productive sites with short rotations. Furthermore, provenance and progeny tests to determine early differentiation among families or to calculate genetic gain could also be seriously affected. It is predominantly as a result of these latter situations that a small number of older stock trials should be monitored well into their 2nd and 3rd decades.

⁶Revel, W.J. 1964. Comparison of four age-classes of Douglas-fir planting stock on various sites. EP 586. B.C. For. Ser., Res. Branch, Victoria, B.C. Unpubl. final report.

7 CONCLUSIONS

The following conclusions are drawn from this study:

- . Stock type significantly influenced the height and the survival of lodgepole pine and white spruce 14 years after planting.
- . Date of planting significantly influenced the survival and height of lodgepole pine and white spruce 14 years after planting.
- . Survival and height of PSB-211 1+0 stock proved excellent for all planting dates and both species.
- . The combined effects of delayed planting and prolonged cold storage were highly detrimental to the survival and growth of bareroot white spruce and lodgepole pine.

8 RECOMMENDATIONS

The initial objectives of this experiment have been met. It has been shown that it is possible to extend the planting season to the entire frost-free period using different stock types. It remains unclear, however, at what point differences owing to variations in planting stock and establishment date become negligible. Because the stands are still intact, monitoring and remeasurement at 20 years and 5-year intervals thereafter should continue until these differences disappear.

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